BEST AVAILABLE COPY

(12) UK Patent Application (19) GB (11) 2 003 692 A

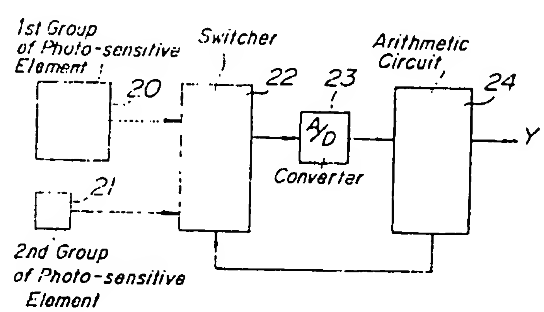
(21) Application No 7834512
(22) Date of filing 24 Aug 1978
(23) Claims filed 24 Aug 1978
(30) Priority data
(31) 52/104713 53/045867
(32) 2 Sept 1977 20 Apr 1978
(33) Japan (JP)
(43) Application published 14 Mar 1979
(51) INT CL² G02B 7/11
(52) Domestic classification H4D 711 747 774 775 782
(56) Documents cited None
(58) Field of Search H4D

(71) Applicant
Olympus Kogaku Kogyo Kabushiki Kaisha
No 43-2 2-Chome
Hatagaya
Shibuya-Ku
Tokyo
Japan
(72) Inventor
Masahiro Aoki
(74) Agents
Haseltine Lake & Co

(54) A method of detecting the state of focus of an optical system

(57) Focus detection is peformed in two stages: (a) by a widely spaced group of photosensitive elements 20; (b) by a second closely spaced group of elements 21. Switcher 22 firstly selects group 20 and the illuminance signal providing contrast information therefrom is fed via A/D converter 23 to arithmetic circuit 24 where a summation calculation is carried out to determine the coarse focus condition. Next, switcher selects the signal from group 21 which, after computation in circuit 24 provides a sharply varying detection signal in the region of focus which is used as a fine measurement. Other signal processing arrangements are given, e.g., using a microcomputer. Various patterns of photosensitive elemens are disclosed.

FIG.5



GB 2 003 692A

2003602

FIG_1

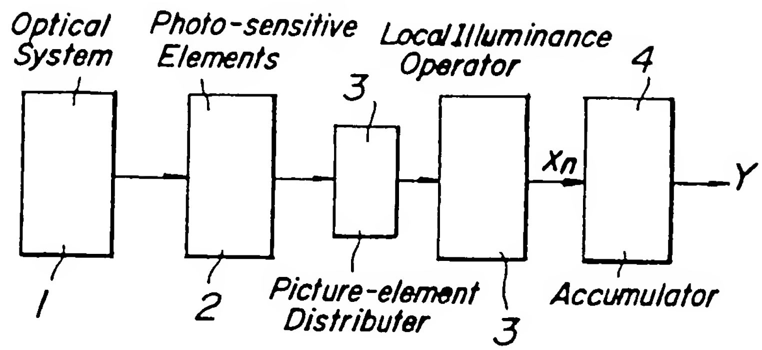


FIG_2A

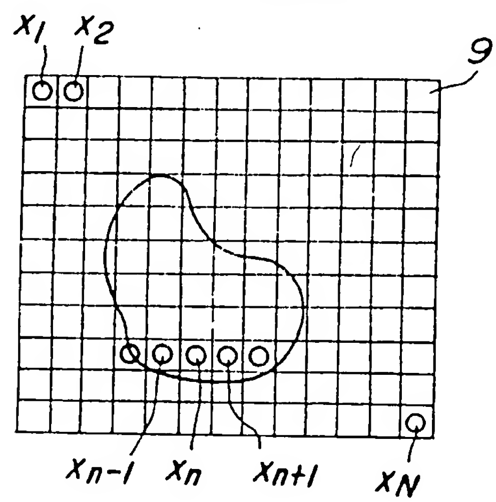
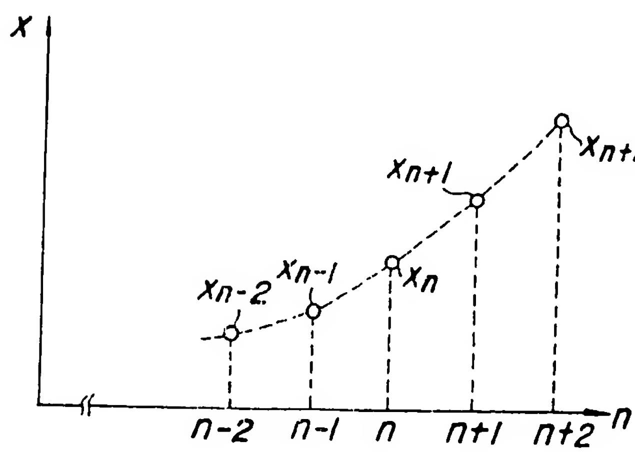


FIG_2B



2003692

FIG_3

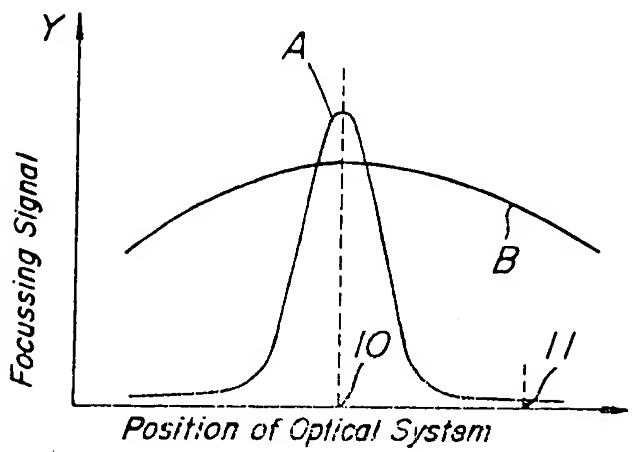


FIG_4

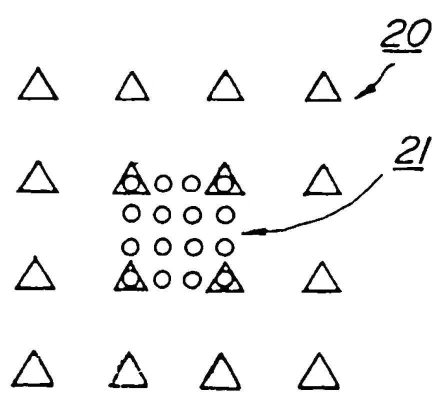


FIG.5

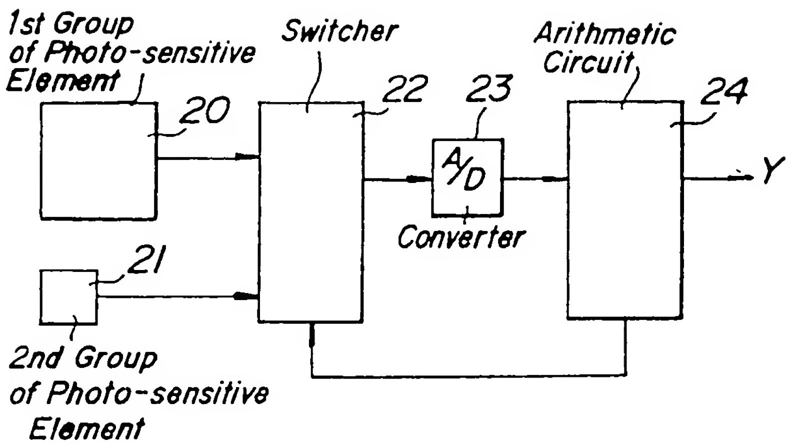

1st Group
of Photo-sensitive
Element
Switcher
Arithmetic
Circuit
20
22
23
24
A/D
Y
Converter
21
2nd Group
of Photo-sensitive
Element

FIG.6

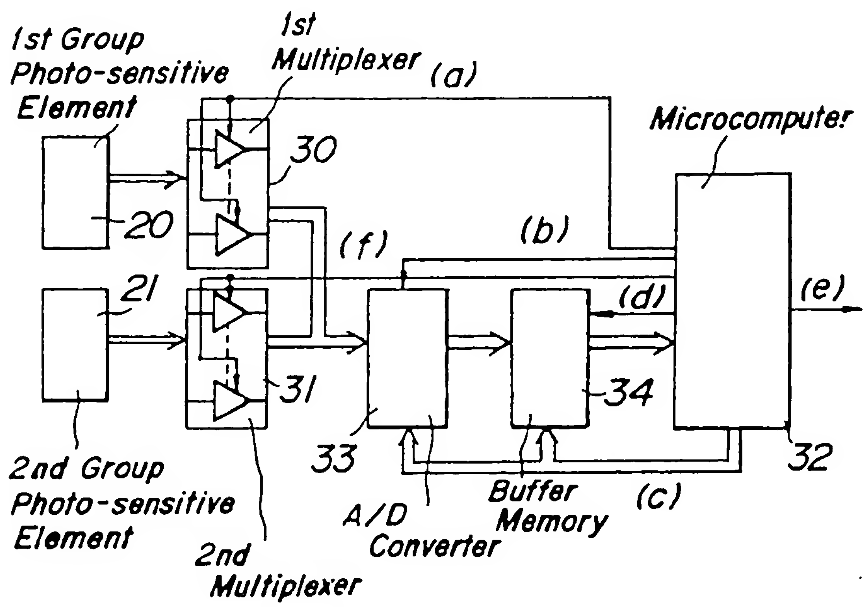

1st Group
Photo-sensitive
Element
1st
Multiplexer
(a)
Microcomputer
30
20
(f)
(b)
21
(d)
(e)
31
34
33
32
2nd Group
Photo-sensitive
Element
Buffer
Memory
(c)
A/D
Converter
2nd
Multiplexer

FIG_7A

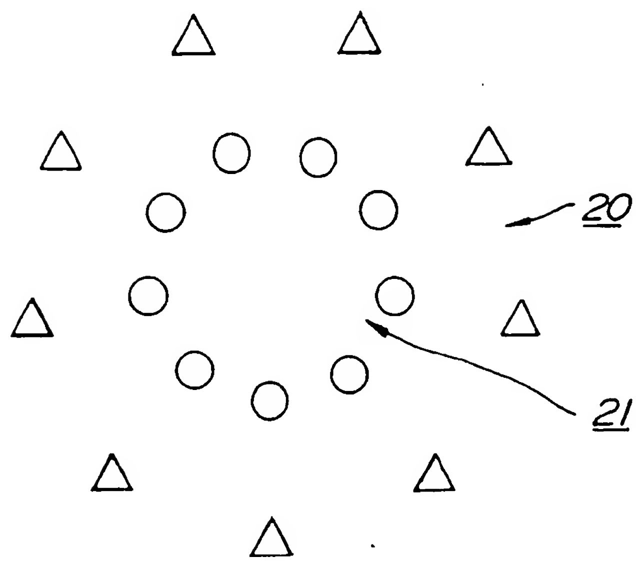


FIG_7B

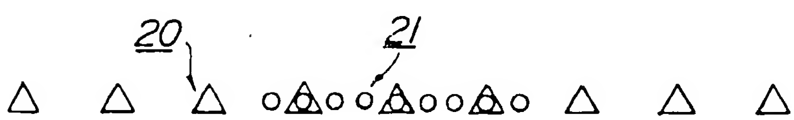


FIG_7C

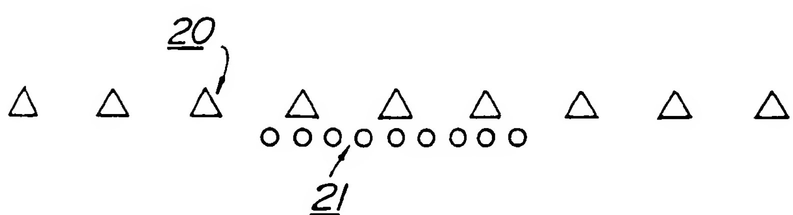


FIG.7D

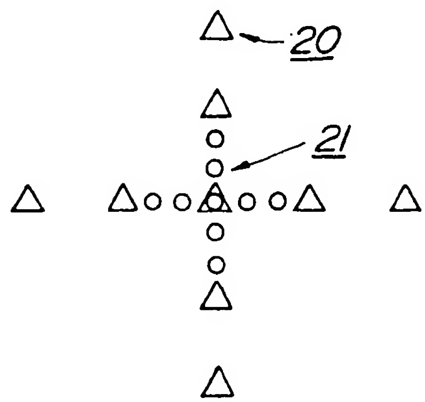


FIG.7E

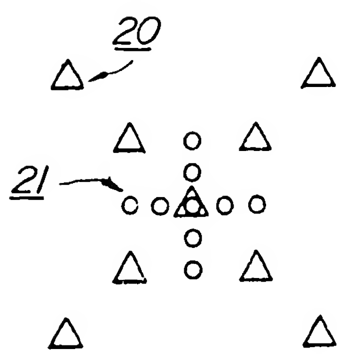
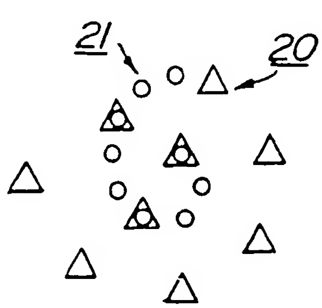


FIG.7F



SPECIFICATION

A method for detecting a focalization or in-focussed-condition of an optical system

The invention relates to a method for detecting a focalization or an in-focussed-condition of an optical system such as a camera lens.

There have been proposed various methods for detecting the in-focussed-condition of the camera lens by detecting a variation in contrast of an image formed by the lens or a variation in concentration or density of the image. In one known method a number of photo-sensitive elements are arranged in a plane on which the image is formed or a plane which lies at a position optically equivalent thereto and a proper arithmetic operation or calculation is performed on an illuminance information derived from the elements to provide an information representing a degree of defocussing. In this known method there is a problem how to determine the in-focussed-condition or focalization with what illuminance information.

An example of the calculation for use in such a focalization detecting method will be explained with reference to Figs. 1 and 2. It should be noted that the present invention is not restricted to such a calculation only. In Fig. 1 a reference numeral 1 denotes an optical system such as a lens system of a camera, which forms an image of an object to be photographed on a plane on which a plurality of photo-sensitive elements 2 and 3 such as photo-diode array are arranged. Each photo-sensitive element produces an illuminance signal representing an amount of illuminance at respective picture element in said image. The picture-element illuminance signals thus obtained are successively supplied to a picture-element distributing section 3 wherein a shift resister supplies in parallel successive sets of illuminance signals of adjacent m picture elements to a local illuminance arithmetic section 4. The arithmetic section 4 calculates a variation of illuminance of the image, i.e. the smoothness of contrast in relation to each group of adjacent m picture elements. The calculated results are accumulated in an accumulator 5. Then the optical system 1 is driven by a suitable means such as a servo motor in response to the accumulated value in such a manner that this value becomes maximum.

Now processes for the illuminance signals in the local arithmetic section 4 and the accumulator 5 will be explained. It is assumed as shown in Fig. 2A that there are arranged N photo-sensitive elements which produce the illuminance signals $x_1, x_2, \ldots x_{n-1}, x_n, x_{n+1}, \ldots x_N$, respectively. In this example three illuminance signals x_{n-1}, x_n and x_{n+1} ($n = 1, \ldots N-1$) derived from three adjacent picture elements are used to calculate an absolute value X_n of difference of second order with respect to the n-th picture element in accordance with the following equation:

$$X_n = |x_{n-1} - 2x_n + x_{n+1}| \qquad (1)$$

In the similar manner the values X_n for successive groups of three adjacent picture elements are calculated. Then the calculated values are accumulated in the accumulator 5 to obtain a sum Y which may be expressed as follows;

$$Y = \sum_n X_n \qquad (2)$$

The difference of second order calculated in accordance with the equation (1) may be considered to represent the smoothness of variation of the illuminance with respect to a position on the image plane and thus this signal Y may be called as a focussing signal.

Fig. 2B is a graph in which an abscissa denotes the number n and an ordinate the magnitude of the illuminace signal x. When three illuminance signals x_{n-1}, x_n and x_{n+1} are aligned on a straight line, the value X_n is zero. This represents that the variation of the illuminance with respect to the position is small and thus the optical system is in a defocussed condition. While the value of X_n increases as the illuminance x_n deviates from a straight line connecting the two illuminances x_{n-1} and x_{n+1}. This means that when the sum Y defined by the equation (2) is large, the variation of illuminance in relation to position is less smooth. Therefore if the optical system 1 is driven in such a manner that the Y reaches its maximum value, then the optical system will be preferably focussed.

In the above mentioned method there is a problem how to arrange the photo-sensitive elements. In order to attain an accurate detection of the in-focussed-condition while the optical system situates near the just focussed position, it is naturally required that the photo-sensitive elements should be arrnaged so finely as close to the resolving power of the optical system. However, such a finely arranged set of photo-sensitive elements does not provide a sufficient defocussing information because a point spread function is rapidly spread as the optical system is out of focus. Namely, the variation of the value Y due to the adjustment of the optical system becomes small. This situation is shown in Fig. 3.

Fig. 3 is a graph illustrating generally a relation between the shift or position of an optical system (on the abscissa) and the focussing signal, for example said Y (on the ordinate). A curve A shows a case where the photo-sensitive elements are finely arranged, i.e., a case where the picture are finely divided into a large number of picture elements, while a curve B shows a case where the photo-sensitive elements are roughly arranged. The former case where the photo-

sensitive elements are finely arranged is suitable for fine focussing since the value of Y drastically changes near the just focussed position 10, while it is not suitable for rough focussing from a far defocussed position 11 since the variation of the value Y is negligibly small. The latter case where the photo-sensitive elements are roughly arranged is not suitable for fine focussing since the value Y varies little near the just focussed position 10, while it is suitable for rough focussing from said position 11 since the value Y varies there comparatively shaply. The rough and fine arrangement of photo-sensitive arrangement have both merits and demerits as described above. It should be noted that in the known methods either one of them or a compromised arrangement of the photo-sensitive elements has been adopted and thus it is impossible to obtain an accurate information about the focalization over a wide range of the position of the optical system.

The present invention has for its object to provide an improved focalization detecting method which provides an accurate information for representing a defocussing and/or focussing condition of an optical system both at a far defocussed position and near an in-focussed-position.

According to the invention a method for detecting a focalization of an optical system by processing illuminance signals derived from a plurality of photo-sensitive elements arranged in an image plane of the optical system comprises

a step for detecting a coarse focussing information by treating the illuminance signals supplied from a first group of the photo-sensitive elements which are arranged in a widely spaced manner; and

a step for detecting a fine focussing information by treating the illuminance signals suplied from a second group of the photo-sensitive elements which are arranged in a closely spaced manner.

The invention will now be described in greater detail with reference to the accompamying drawings, wherein:

Figure 1 is a block diagram showing an apparatus for detecting a focalization of an optical system;

Figure 2A is a schematic view illustrating an arrangement of a number of photo-sensitive elements in an image plane;

Figure 2B is a graph showing a variation in contrast of the image;

Figure 3 is a graph representing variations of focussing signals with respect to a position of an optical system;

Figure 4 is a schematic view depicting an embodiment of an arrangement of photo-sensitive elements according to the invention;

Figures 5 and 6 are diagrams illustrating two embodiments of a focalization detecting apparatus for carying out the method according to the invention; and

Figures 7A to 7F are schematic views showing several embodiments of the arrangements of the photo-sensitive elements according to the invention.

Fig. 4 is a schematic view showing an embodiment of arrangement of photo-sensitive elements for use in the focalization detecing method according to the invention. In this embodiment there are provided two groups of photo-sensitive element arrays, a first group 20 comprising 16 photo-sensitive elements arranged in a widely spread manner as a lattice and a second group 21 including 16 photo-sensitive elements arranged in a closely spaced manner also as a lattice in a space surrounded by innermost elements of the first group. In Fig. 4 the elements belonging to the first group 20 are symbolized by a triangular mark and those belonging to the second group 21 by a circular mark. It should be noted that the shapes of the marks do not represent a shape of an incidence surface of the elements. As can be seen from Fig. 4 the innermost four elements of the first group 20 operate as elements of the second group 21. In other words these four elements are common to both the first and second groups.

Fig. 5 is a block diagram illustrating an embodiment of the focalization detecting apparatus for realizing the method of the invention. The photo-electrically converted signals produced by the two groups of photo-sensitive elements are supplied to a switcher 22. At first the switcher is acturated in a first position wherein the illuminance signals from the roughly arranged photo-sensitive elements of the first group 20 are supplied to an arithmetic unit 24 via an analog-to-digital converter 23. The arithmetic unit comprises the picture-element distributing section 3, the local illumination arithmetic section 4 and the accumulator 5 shown in Fig. 1 and calculates a coarse focussing signal Y representing the degree of defocussing in accordance with the equation (1). Then the lens system is driven in response to this coarse focussing signal Y in such a manner that the signal Y increases toward its maximum value. As described above the slope of this coarse focussing signal Y obtained from the first group 20 is comparatively steep, so that the lens system can be positively driven into a proximity of the in-focussed-position even if a starting position of the lens system is far from the in-focussed-position.

Then the switcher 22 is changed into a second position in which the illuminance signals derived from the photo-sensitive elements of the second group 21 are supplied to the arithmetic unit 24 through the analog-to-digital converter 23 to produce a fine focussing signal Y also in accordance with the equation (1). Since the lens system has already roughly focussed during the above mentioned focuss-

ing control with the aid of the coarse focussing signal, it is possible to bring precisely the lens system into the in-focussed-position with the aid of the fine focussing signal. In this manner according to the invention an effective and precise focussing operation can be achieved even if the lens system situates initially at any defocussed position.

Fig. 6 is a block diagram showing another embodiment of the focalization detecting apparatus for carrying out the method according to the invention. The output illuminance signals from the first and second groups 20 and 21 of photo-sensitive elements are supplied in parallel to inputs of first and second analog multiplexers 30 and 31, respectively. The number of the inputs of each analog multiplexer is at least same as that of the elements of each group.

There is provided a control device 32 such as a microcomputer for controlling the operation of the multiplexers 30 and 31. At first the control device 32 provides a coarse detection order signal (a) to the first multiplexer 30. Then the multiplexer supplies in parallel the output illuminance signals from the first photo-sensitive element group 20 to an analog-to-digital converter 33 which has the same number of parallel inputs as that of the photo-sensitive elements of the first group 20. At the same time the control device 32 provides a conversion order signal (b) to the A-D converter 33 which converts the analog signals into digital signals. Further the control device 32 supplies an address signal (c) to the converter 33 and a buffer memory 34 to store the digital signal derived from the photo-sensitive element corresponding to the relevant address in a corresponding address position of the memory 34. This storing operation is effected in succession for the digital signals from the photo-sensitive elements by changing successively the address signal (c) so as to store the digital signals representing the illuminance information of the photo-sensitive elements of the first group 20 in the buffer memory 34.

Then the microcomputer 32 produces a read-out signal (d) for reading out the digital signals for calculating a coarse focussing signal Y in accordance with a given contrast evaluation function such as the above mentioned equation (2), i.e.

$$Y = \sum_{n} |x_{n-1} - 2x_n + x_{n+1}|.$$

The coarse focussing signal Y represents the defocussed-condition of the optical system. It is possible to derive from the signal Y an indication signal to indicate visially or acoustically the defocussed- or in-focussed-condition. In this case a user can adjust the optical system in response to the indication thus formed. Alternatively the coarse focussing signal may be used to produce a signal for driving the optical system to adjust coarsely the system near the in-focussed-position.

Next the microcomputer 34 releases the coarse detection order signal (a) to render the first multiplexer 30 inoperative and supplies a fine detection order signal (f) to the second multiplexer 31. Then the fine focalization detecting operation is carried out in the manner similar to that of the coarse focalization detecting operation to produce a fine focussing signal Y on the basis of the contrast evaluation function with respect to the illuminance signals supplied from the photo-sensitive elements of the second group 21. By means of the fine focussing signal thus obtained it is possible to adjust precisely the optical system at the just in-focussed-position or to indicate accurately the in-focussed-condition.

The present invention should not be limited to the embodiments explained above, but many modifications and variations can be conceived within the scope of the invention. For example, many other synthesizing methods or arithmetic calculations for deriving the focussing signal Y may be utilized. Although in the above embodiment the focussing signal Y is obtained on the basis of the difference of second order of illuminance signals from adjacent three picture elements, the signal Y may be derived by calculating a difference of the third order of the illuminance signals. In the above mentioned embodiment there are actually provided the two groups of photo-sensitive elements, but use may be made of an arrangement in which a number of photo-sensitive elements are arranged equidistantly relative to each other and given elements for effectng the coarse and fine focussing detections may be selected. Although in the above embodiment the photo-sensitive elements are arranged in a lattice, other various arrangements may be conceived.

Figs. 7A to 7F are schematic diagrams for showing several embodiments of the arrangements of the photo-sensitive elements. In an embodiment of Fig. 7A widely spaced photo-sensitive elements of the first group 20 and closely spaced photo-sensitive elements of the second group 21 are arranged concentrically. This concentrical arrangement permits an omnidirectional investigation of illuminance distribution, while the lattice arrangement allows only an orthogonal investigation.

Fig. 7B shows another embodiment in which the photo-sensitive elements of the first and second groups 20 and 21 are arranged in line. In this arrangement three elements are commonly used for the first and second groups.

Fig. 7C is an alternative embodiment of that shown in Fig. 7B in which no photo-sensitive element is commonly used for the first and second groups 20 and 21.

In embodiments shown in Figs. 7D and 7E the photo-sensitive elements of each of the

first and second groups 20 and 21 are arranged in a cross-shaped manner. In Fig. 7E the direction of the cross of the first group 20 is inclined by an angle of 45 degrees relative to the second group 21.

Fig. 7F illustrates still another embodiment wherein the photo-sensitive elements of the first and second groups 20 and 21 are arranged on a spiral at different pitches.

The embodiments of Figs. 7B and 7C have an advantage that a longer base length can be achieved and the embodiments illustrated in Figs. 7A and 7F have a higher directional sensitivity.

According to the invention the number of the groups of the photo-sensitive elements should not be limited to two, but three or more groups may be used. For example in the embodiment shown in Fig. 7A a third photo-sensitive element group may be provided within a circular space surrounded by the elements of the second group 21.

Further in the embodiment shown in Fig. 6 the buffer memory 34 may be dispensed with, provided that the output signals from the A-D converter 33 do not change until a next conversion order signal is supplied from the microcomputer 32. The reading out of the digital illuminance signals may be effected in an arbiterary order instead of a regular order.

In the above embodiments the numbers of the photo-sensitive elements of the first and second groups are made equal to each other, but these numbers may be different from each other. Moreover the photo-sensitive elements may be consitituted by a self-scanning type solid state device such as CCD.

In the above embodiments the contrast evaluation function for deriving the coarse focussing signal is made identical with that for deriving the fine focussing signal, but these contrast evaluation functions may be different from each other.

CLAIMS

1. A method for detecting a focalization or in-focussed-condition of an optical system by processing illuminance signals derived from a plurality of photo-sensitive elements arranged in a plane on which an image of an object is formed by the optical system comprising

a step for detecting a coarse focussing information by treating the illuminance signals supplied from a first group of the photo-sensitive elements which are arranged in a widely spaced manner; and

a step for detecting a fine focussing information by treating the illuminance signals supplied from a second group of the photo-sensitive elements which are arranged in a closely spaced manner.

2. A method according to claim 1, wherein the photo-sensitive elements of the second group are arranged in a space surrounded by the photo-sensitive elements of the first group.

3. A method according to claim 2, wherein the photo-sensitive elements of the first group are arranged as a lattice and the photo-sensitive elements of the second group are arranged as a lattice in a space surrounded by the innermost elements of the first group.

4. A method according to claim 2, wherein the photo-sensitive elements of the first group are arranged along a first circle and the photo-sensitive elements of the second group are arranged along concentric second circle having a diameter smaller than that of the first circle.

5. A method according to claim 2, wherein the photo-sensitive elements of the first and second groups are arranged in line.

6. A method according to claim 2, wherein the photo-sensitive elements of the first and second groups are arranged in a cross-shaped manner.

7. A method according to claim 6, wherein directions of the cross-shaped arrangements of the first and second groups are made different from each other.

8. A method according to claim 2, wherein the photo-sensitive elements of the first and second groups are arranged along a spiral.

9. A method according to any one of the claims 2 to 8, wherein at least one photo-sensitive element is commonly used for the first and second groups.

10. A method according to claim 1, wherein all of the photo-sensitive elements are arranged substantially equidistantly and the first and second groups are composed by selecting given elements distributed widely and closely, respectively.

11. A method according to claim 1, wherein the number of photo-sensitive elements of the first group is made equal to that of the second group.

12. A method according to claim 1, wherein the number of the photo-sensitive elements of the first group is made different from that of the second group.

13. A method according to claim 1, the illuminance signals from the photo-sensitive elements of the first group are supplied through a switcher and an analog-to-digital converter to an arithmetic calculation device to form a coarse focussing signal in accordance with a contrast evaluation function and then the illuminance signals from the photo-sensitive elements of the second group are supplied through the switcher and the analog-to-digital converter to the arithmetic calculation device to derive a fine focussing signal in accordance with a contrast evaluation function.

14. A method according to claim 1, wherein the contrast evaluation function for deriving the coarse focussing signal is made identical with that for deriving the fine focussing signal.

15. A method according to claim 14, wherein said contrast evaluation function is given by

$$Y = \sum_n |x_{n-1} - 2x_n + x_{n+1}|,$$

wherein x_{n-1}, x_n and x_{n+1} represent illuminance signals produced by three adjacent photo-sensitive elements.

16. A method according to claim 1, wherein the illuminance signals derived from the photo-sensitive elements of the first and second groups are supplied to first and second analog multiplexers, respectively which are controlled by coarse and fine detection order signals supplied from a control device, upon receiving the coarse detection order signal the first multiplexer supplies the illuminance signals from the photo-sensitive elements of the first group to an analog-to-digital converter which is also controlled by the control device to produce digital illuminance signals which are further supplied to the control device, the control device derives the coarse focussing signal in accordance with a given contrast evaluation function, and upon receiving the fine detection order signal the second multiplexer supplies the illuminance signals from the photo-sensitive elements of the second group to the control device through the analog-to-digital converter, the control device calculates the fine focussing signal from the digital illuminance signals in accordance with a given contrast evaluation function.

17. A method according to claim 16, wherein the digital illuminance signals from the analog-to-digital converter are supplied to a buffer memory which stores the illuminance signal from respective element in a corresponding address position under the control of an address signal supplied from the control device.

18. A method according to claim 16, wherein the control device is composed of a microcomputer.

19. A method according to claim 16, wherein the illuminance signals from the photo-sensitive elements are supplied to the multiplexers in a serial mode.

20. A method according to claim 16, wherein the illuminance signals from the photosensitive elements are supplied to the multiplexers in a parallel mode.

21. A method according to claim 16, wherein the analog illuminance signals from the photo-sensitive elements of either first and second groups are supplied to the analog-to-digital converter in a serial mode.

22. A method according to claim 16, wherein the analog illuminance signals from the photo-sensitive elements of either first and second groups are supplied to the analog-to-digital converter in a parallel mode.

23. A method according to claim 16, wherein the contrast evaluation function for deriving the coarse focussing signal is made identical with that for deriving the fine focussing signal.

24. A method according to claim 23, wherein the contrast evaluation function is given by

$$Y = \sum_n |x_{n-1} - 2x_n + x_{n+1}|,$$

wherein x_{n-1}, x_n and x_{n+1} are the digital illuminance values of three adjacent photo-sensitive elements.

25. A method for detecting a focalization or in-focussed-condition of an optical system substantially as hereinbefore described with reference to any one of Figs. 4 to 7F of the accompanying drawings.

Printed for Her Majesty's Stationery Office by Burgess & Son (Abingdon) Ltd.—1979.
Published at The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained

XP-002180038

PD: 00-00-1994 (3)

P: 190 - 192

mirror synchronized to the focusing movement images a zone of the subject onto a linear photodetector array, and this image as a dynamic response is compared to the static image response of the subject area as seen by a second fixed mirror and matching detector array. The subsequent comparison of results gives a correlation signal that is a maximum when both mirrors image the same zone. This is an analogue of an optical coincidence rangefinder (see Section 57.3). This signal then locks the focusing travel by means of a solenoid-operated pawl. This system works best in high light levels and is dependent on efficient signal-processing circuitry.

The Canon CAFS system uses no moving parts and has two static mirrors to image zones of the scene across a linear CCD array containing some 240 of these self-scanning elements. The image of the area selected for focusing is compared to adjacent image areas along the array, and maximum correlation gives a 'base' or distance between the two correlated regions which relates to subject distance by an angular subtense. This continuous self-scanning triangulation system has also been used to operate the motorized focusing control of either a cine camera or video camcorder.

The optics of triangulation systems for distance measurement using emitted light and a multi-segmented linear detector base have been described in detail by Ji and Leu (1989).

The systems described work well with standard, semi-wide angle or wide angle lenses (50 to 28 mm) down to distances of some 0.5 to 0.3 m in so-called 'compact' 35 mm cameras with fixed prime lenses. Cameras equipped with zoom lenses or converter systems to increase focal length to some 105 mm rely upon a consequent small maximum aperture of some *f*/8 to maintain accuracy by the latitude given by the depth of field. The measurement accuracy also limits maximum aperture to *f*/3.5 or *f*/2.8 but a very few cameras have offered the larger aperture of *f*/2 for a 40 mm lens. Focusing accuracy can be judged by the number of distinct 'focus zones' to which the lens may be set. These can be less than 10 or more than 100 depending on the parameters of the lens. Typically, 18 zones may be assigned for focus from infinity to 1 m, then, in close-focus mode, another 18 between 1 m and 0.3 m, as greater focus accuracy is needed.

The problem of parallax errors and measuring accuracy in video camcorders which use close-focusing zoom lenses has been solved by actually using a beamsplitter located inside the lens elements to emit an IR beam to the subject, which is then monitored by a photodetector array behind a separate, adjacent lens. The detector output sets focus by moving the focusing group of the zoom lens and acts in a dynamic mode.

One problem with IR beams is that some subjects, such as black cloth or window glass, may have very low or very high IR reflectance respectively, so that absorption or specular reflection in another direction do not provide an adequate level or return signal to the detector. The autofocus system may have an 'infinity lock' provided to take pictures of subjects through glass, otherwise the lens will focus on the glass. The system can, however, operate even in total darkness.

In conjunction with a camera equipped with a motorized zoom lens, the detector array output can also be used to maintain the principal subject region, such as a portrait subject, at a constant magnification in the picture as subject distance is varied, by corresponding alteration of the focal length.

Ranging methods are best suited to fixed lens cameras and not to interchangeable lens cameras where extremes of focal length and subject distance are involved and accuracy is inadequate.

In cameras with integral flash units, automatic flash exposure is given by the *Flashmatic* method, where the distance information from the AF system is used to set the *f*-number of the lens according to the *flash factor* of the unit and a full-power flash given. This is a lower cost alternative to 'quenched' automatic flash.

21.4.2 Image contrast measurement

A through-focus determination of image contrast, as measured by the width of the PSF or the slope of the LSF, shows that contrast is at a maximum at optimum focus and decreases either side of this point. Visual focusing on a ground-glass screen (GGS) is essentially a contrast-judging process, aiming for maximum value. In order to automate this contrast measurement or judgement process to provide an autofocus system which measures the actual image itself, rather than use a supplementary opto-electronic system for autoranging, the image illumination gradient must be converted into electrical signals in a form suitable for processing by digital circuitry. Again, a linear CCD array is found suited to focus detection and evaluation as shown in Figure 21.5. Precise indication of the focus of edge details are given from the self-scanning process and comparison of the outputs of adjacent CCD elements. No moving parts are involved. Integrated circuit techniques enable two or more adjacent arrays plus all the signal-processing circuitry for contrast measurement and correlation to be supplied on a small 'chip' which can be located in an equivalent image plane in the camera or even in the barrel of an interchangeable lens. A favoured camera location is in the base of the dark chamber with a 'piggy-back' mirror behind the main reflex mirror focusing a small central zone of the FOV on to the detector arrays. The reflex mirror must be partially transparent in this area or carry an unusual pattern of slits to transmit a percentage of the incident light while

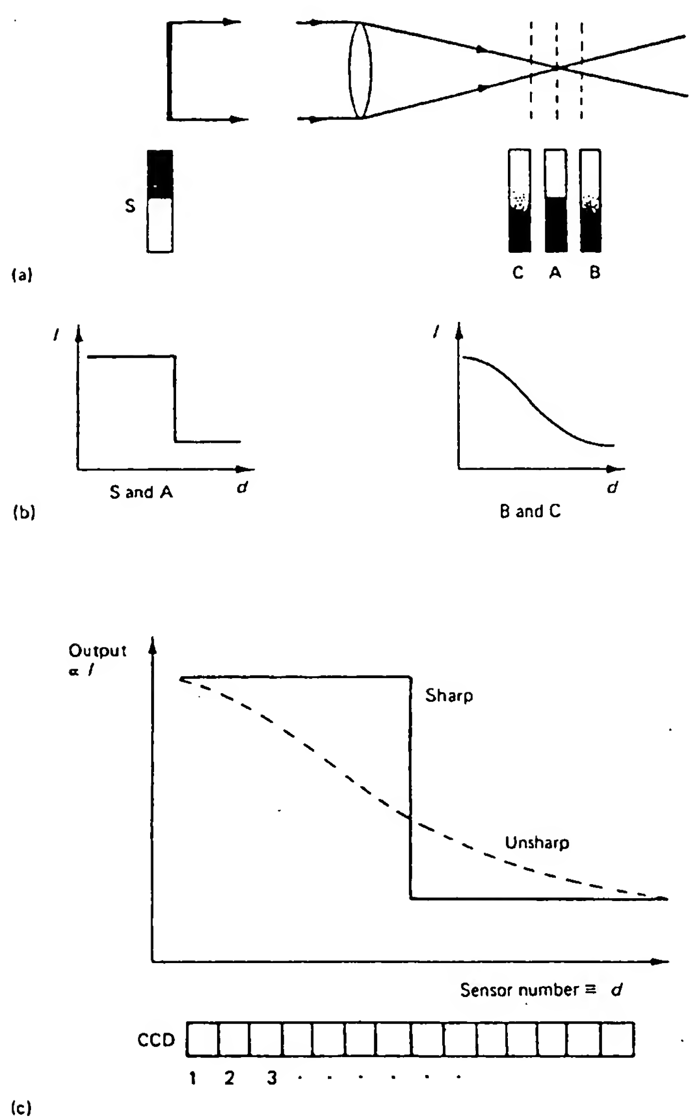


Figure 21.5 Focus Detection by a Linear CCD Array
(a) Subject S imaged in sharp focus at A, but unsharp at C and B. (b) Intensity profiles of S and A and of B and C. (c) Intensity profile as measure of focus determined by linear array of charge coupled devices (CCD) whose output is proportional to intensity and where sensor number corresponds to distance. Signal-processing techniques detect the sharp or unsharp characteristic.

giving uniform illumination over the detector array. Slits are preferred where the array has a supplementary beamsplitter system as described below, and there will be problems with the use of linear polarizing filters over the camera lens. The autofocus system may not operate unless a circular polarizing filter is substituted due to behaviour of the beamsplitter.

In order to provide information on the necessary corrective movement of the focusing action to either the focusing motor in the AF mode or to the user in the alternative *assisted-focusing mode*, a complex beamsplitter using partially coated patterned mirrors can be used in conjunction with two or three adjacent CCD arrays (Figure 21.6). A triple array has one in the focal plane, one in front and one behind, so that comparison of their output unambiguously indicates 'correct focus' or 'too near' or 'too far'. Suitable corrective action can then be taken.

A twin array is positioned one in front of and one behind the equivalent focal plane to signal focus errors, but less efficiently.

This system tends to be slow in operation due to signal processing algorithms, requires high light levels

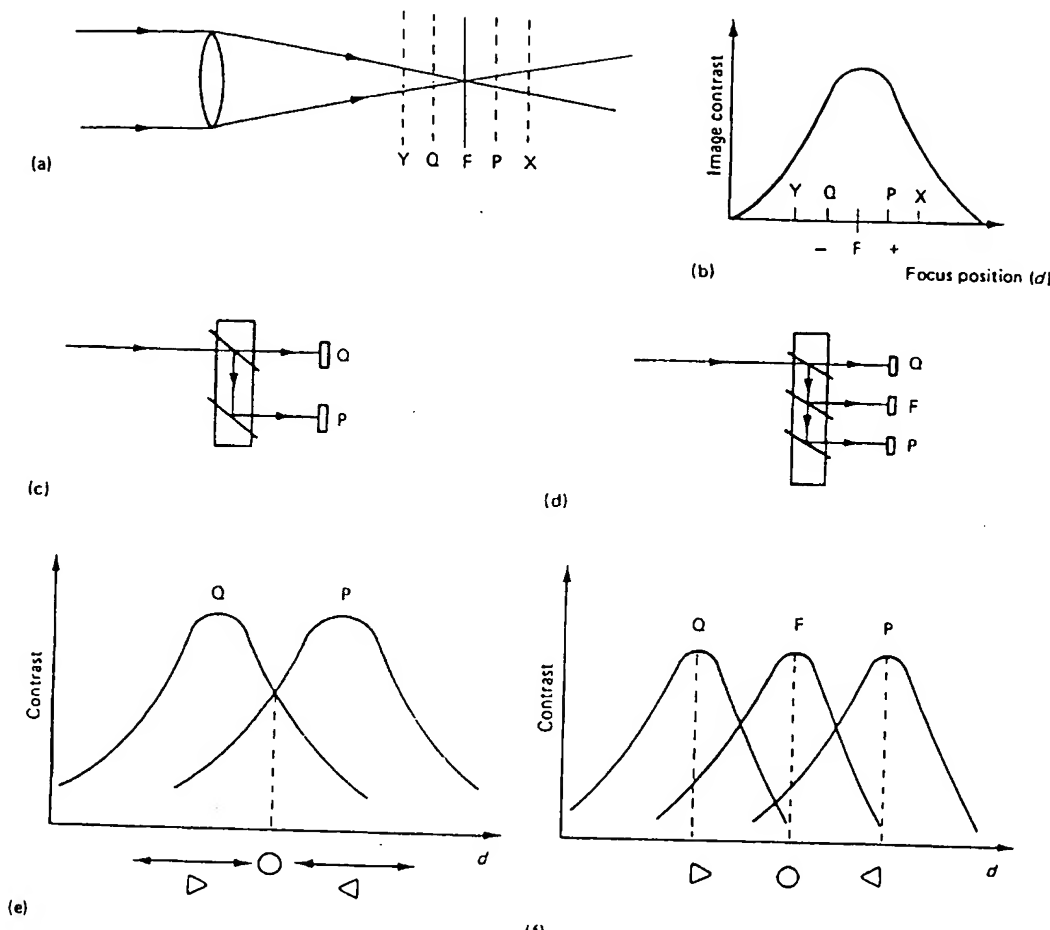


Figure 21.6 Autofocus Using Image Contrast Measurements
(a) Sharp image at F with maximum contrast. (b) Variation of contrast with focus position. (c) and (d) Beamsplitters in equivalent focal planes to compare contrast at Q and P or at Q, F and P using linear CCD arrays. (e) and (f) Double or triple outputs of CCD arrays compared by signal-processing techniques to indicate best focus at O or generate signals in viewfinder or operate a servomotor.

for operation, and is defeated by a range of subjects with low contrast or contrast gradients. It has largely been superceded by phase detection methods.

21.4.3 Exit pupil measurements

Introduced in 1978, the Honeywell TCL (through camera lens) module (Figure 21.7) uses two sets of 24 pairs of photodetectors aligned behind a similar linear array of micro lenses as condensers to monitor the left- and right-hand halves of the exit pupil of the camera lens. The array is located in a geometrically equivalent focal plane. Both halves of the exit pupil are equally bright when the subject is in focus and unevenly shaded when it is not. The separation of a pair of detectors is matched to lens aperture (pupil diameter), one set being suited to $f/1.4$ to $f/2.8$, the other, of greater separation, being suited to $f/2.8$ or less. A field lens provides uniform illumination to the whole set. Each micropair of detectors records the right or left half of the exit pupil and is scanned accordingly for signal processing and correlation.

The Leiz Correphot system uses an oscillating prismatic grating to split the pupil optically to two sets of detectors but at present is not in commercial use.

The various systems described normally use a